Field Evaluation
Purple Air PM Sensor

South Coast
AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 02/19/2016 to 04/19/2016, three **Purple Air PM Sensors** were deployed at our (SCAQMD) Rubidoux station and ran side-by-side with two Federal Equivalent Method (FEM) instruments measuring the same pollutant

- _Purple Air Sensor (3 units tested):_
  - Particle sensors (optical; non-FEM)
  - Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} mass concentration ($\mu g/m^3$)
  - Unit cost: ~$150
  - Time resolution: 20-sec
  - Units IDs: 22d0, 2336, b610

- MetOne BAM (_reference method_):
  - Beta-attenuation monitors (FEM)
  - Measures $PM_{2.5}$ & PM_{10} mass ($\mu g/m^3$)
  - Unit cost: ~$20,000
  - Time resolution: 1-hr

- GRIMM (_reference method_):
  - Optical particle counter (FEM)
  - Uses proprietary algorithms to calculate total $PM_{1.0}$, $PM_{2.5}$, and PM_{10} mass from particle number measurements
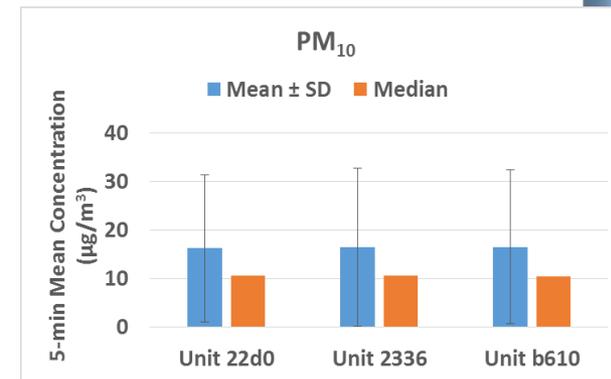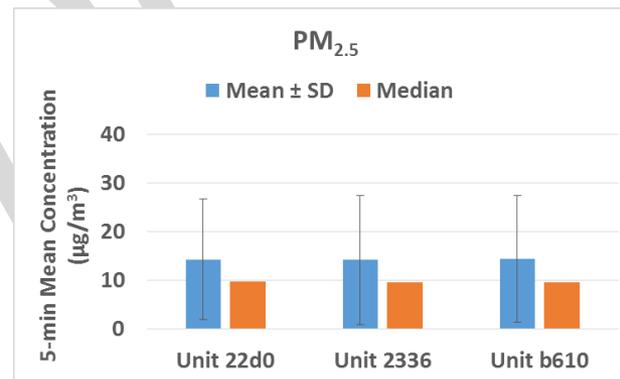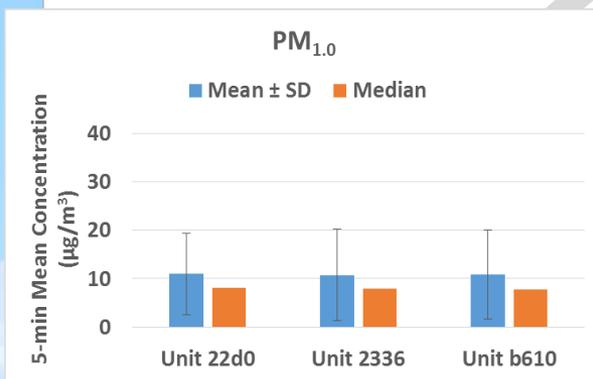 - Unit Cost: ~$25,000 and up
  - Time resolution: 1-min

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery for $PM_{1.0}$, $PM_{2.5}$ and PM_{10} from all three Purple Air Sensors was 99.9%

Purple Air sensors; intra-model variability

- Very low measurement variations were observed between the three Purple Air devices for $PM_{1.0}$, $PM_{2.5}$ and PM_{10} mass concentrations (µg/m^3)
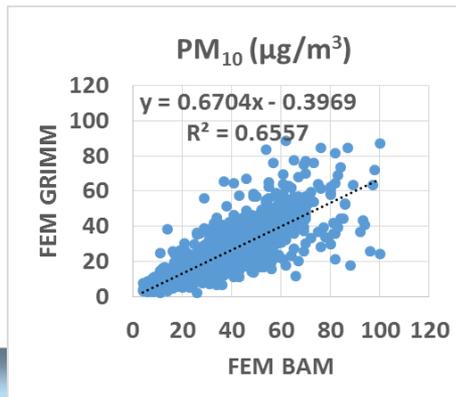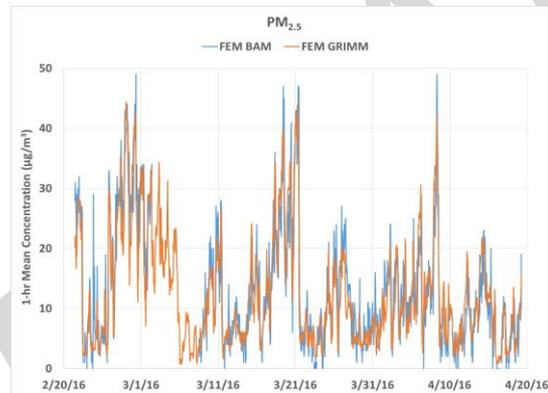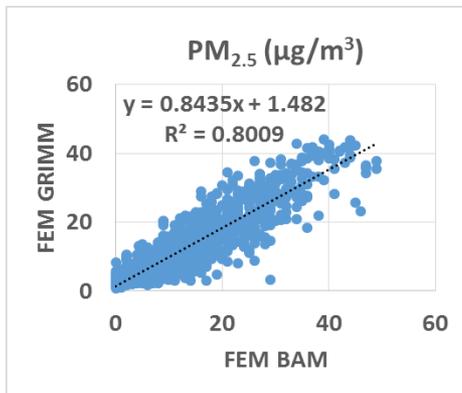
Data validation & recovery

- Basic QA/QC procedures were used to validate the collected FEM data (i.e. obvious outliers, negative values and invalid data-points were eliminated from data-set)
- $PM_{2.5}$ & PM_{10} data recovery was 100 % for the GRIMM and 87 % for the BAM
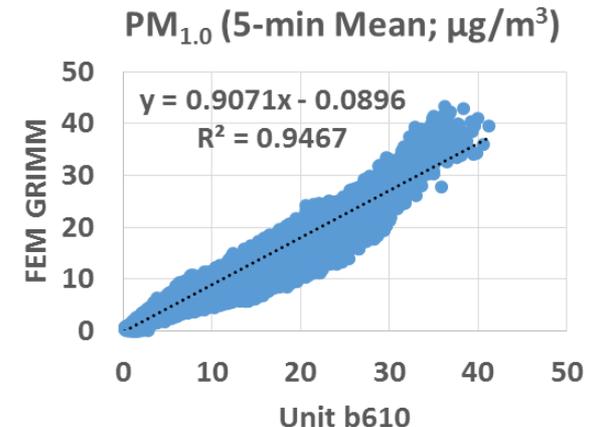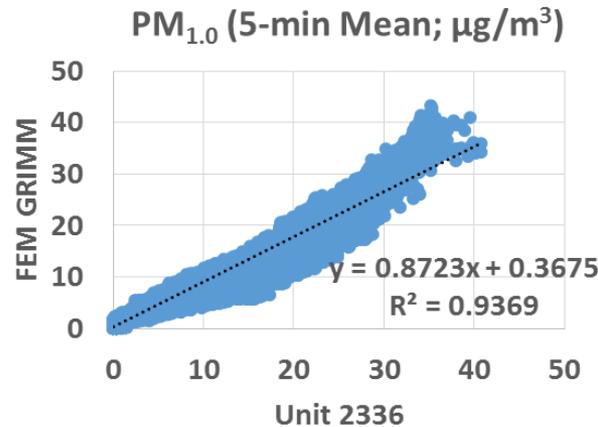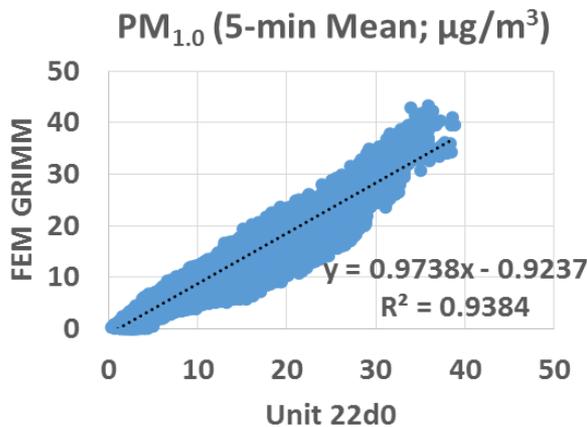
Equivalent methods: BAM vs GRIMM

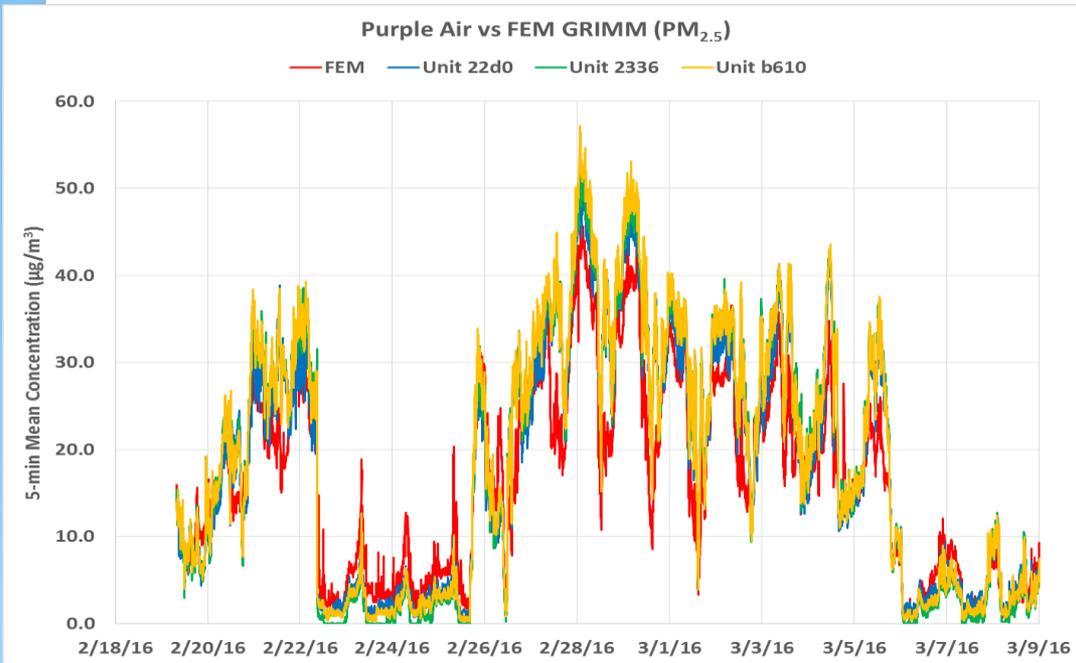- Good correlation between the two equivalent methods for $PM_{2.5}$ & PM_{10}
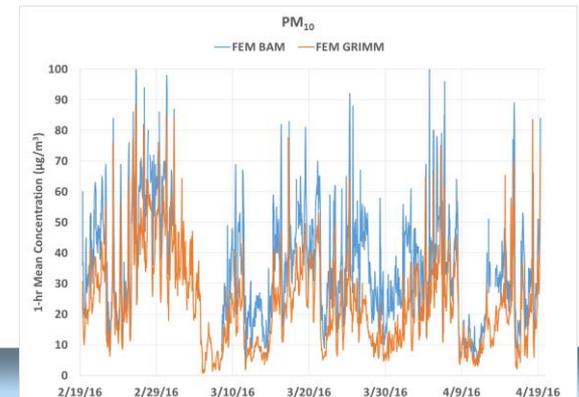
Purple Air Sensor vs FEM GRIMM (PM$_{1.0}$ Mass; 5-min mean)
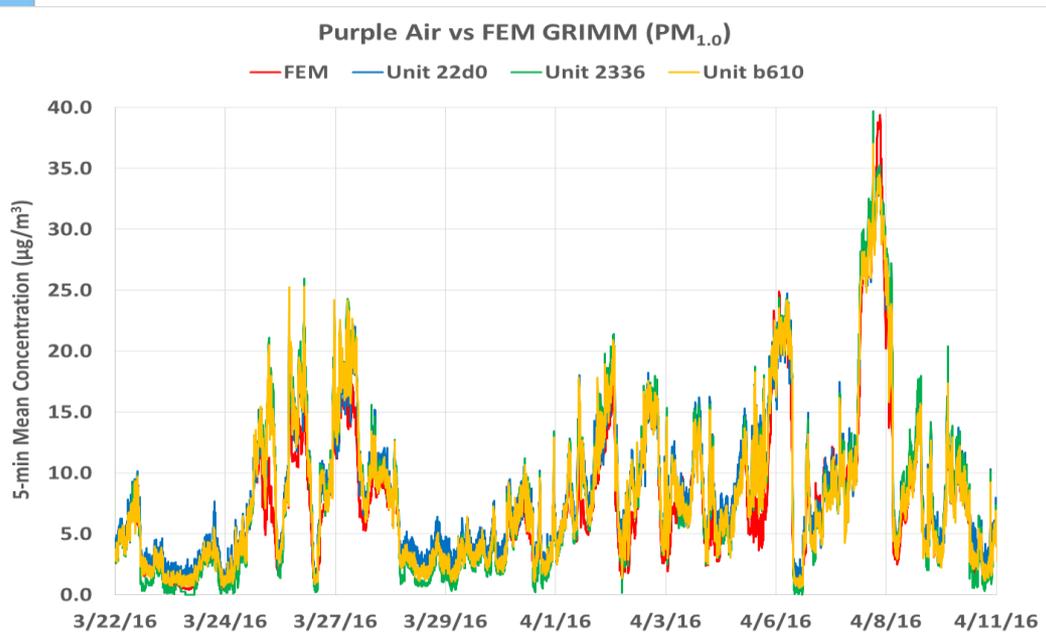
Purple Air vs FEM GRIMM (PM$_{1.0}$)
— FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{1.0}$ mass measurements correlate well with the corresponding FEM GRIMM data ($R^2 > 0.93$)
- The three sensor units tracked the diurnal PM variations recorded by the FEM GRIMM instrument well
- Measurements from all three Purple Air devices are quite accurate when compared to the corresponding FEM data
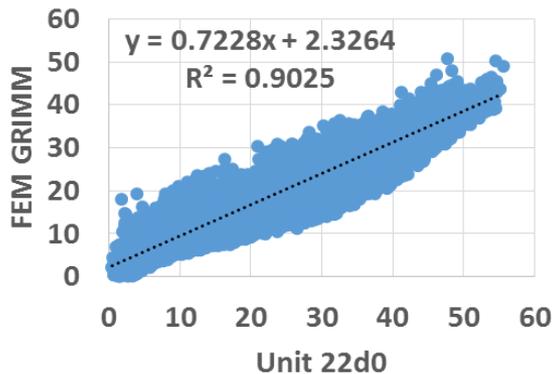

PM$_{1.0}$ (5-min Mean; µg/m^3)
$y = 0.9738x - 0.9237$
$R^2 = 0.9384$

PM$_{1.0}$ (5-min Mean; µg/m^3)
$y = 0.8723x + 0.3675$
$R^2 = 0.9369$

PM$_{1.0}$ (5-min Mean; µg/m^3)
$y = 0.9071x - 0.0896$
$R^2 = 0.9467$

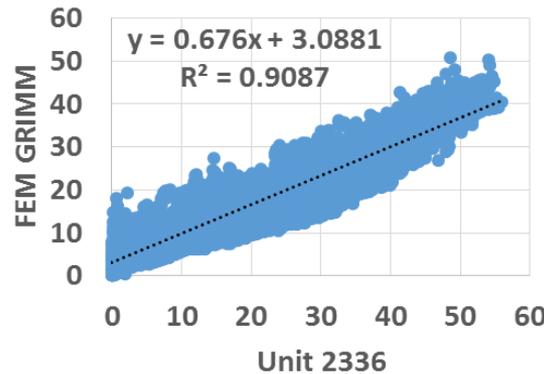# Purple Air Sensor vs FEM GRIMM (PM$_{2.5}$ Mass; 5-min mean)

- Purple Air PM$_{2.5}$ mass measurements correlate well with the corresponding FEM GRIMM data (R^2 > 0.90)
- The three sensor units track the diurnal PM variations recorded by the FEM GRIMM instrument well
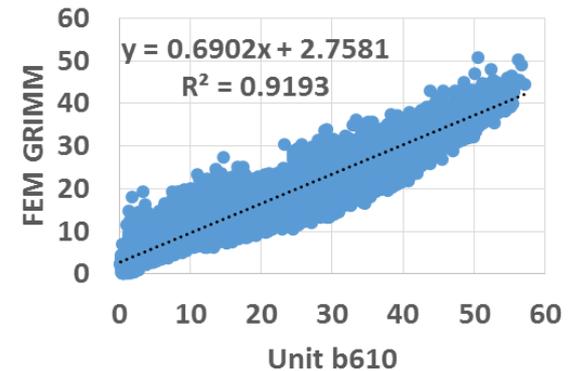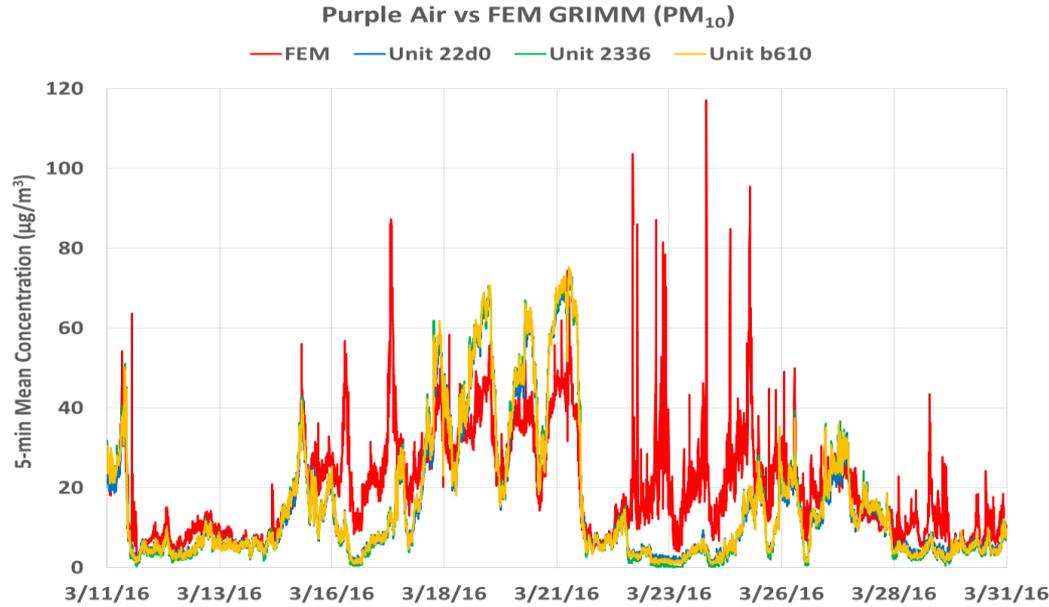
Purple Air Sensor vs FEM GRIMM (PM_{10} Mass; 5-min mean)

Purple Air vs FEM GRIMM (PM_{10})

Legend: FEM — Unit 22d0 — Unit 2336 — Unit b610

y-axis: 5-min Mean Concentration (μg/m³) — 0, 20, 40, 60, 80, 100, 120

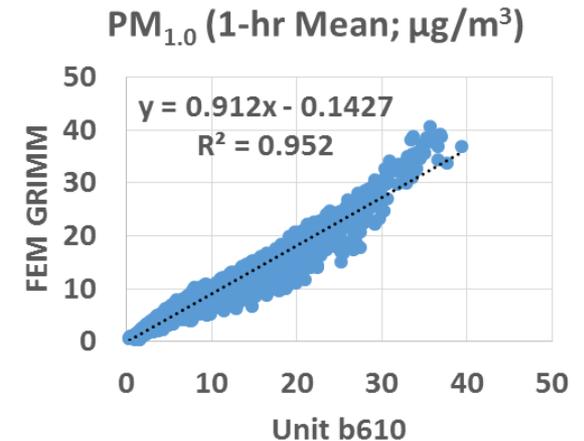x-axis: 3/11/16, 3/13/16, 3/16/16, 3/18/16, 3/21/16, 3/23/16, 3/26/16, 3/28/16, 3/31/16

- Purple Air PM_{10} mass measurements show a modest correlation with the corresponding FEM GRIMM data ($R^2 < 0.41$)
- The three sensor units do not always track the diurnal variations recorded by the FEM GRIMM instrument
- Purple Air PM_{10} measurements are underestimated with respect to the corresponding FEM GRIMM data

PM_{10} (5-min Mean; μg/m³)

$y = 0.6651x + 12.85$
$R^2 = 0.3933$

y-axis: FEM GRIMM — 0, 50, 100, 150
x-axis: Unit 22d0 — 0, 50, 100, 150

PM_{10} (5-min Mean; μg/m³)

$y = 0.6206x + 13.378$
$R^2 = 0.3969$

y-axis: FEM GRIMM — 0, 50, 100, 150
x-axis: Unit 2336 — 0, 50, 100, 150

PM_{10} (5-min Mean; μg/m³)

$y = 0.6467x + 12.932$
$R^2 = 0.4124$

y-axis: FEM GRIMM — 0, 50, 100, 150
x-axis: Unit b610 — 0, 50, 100, 150
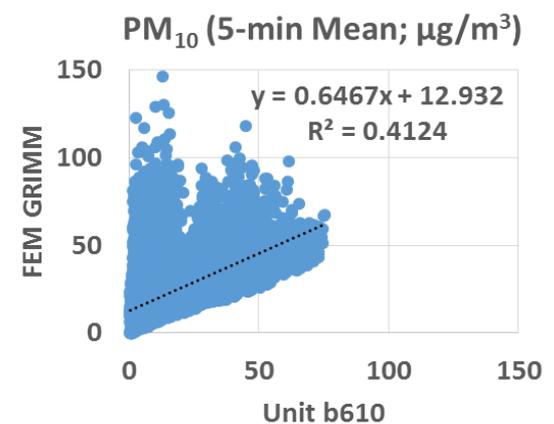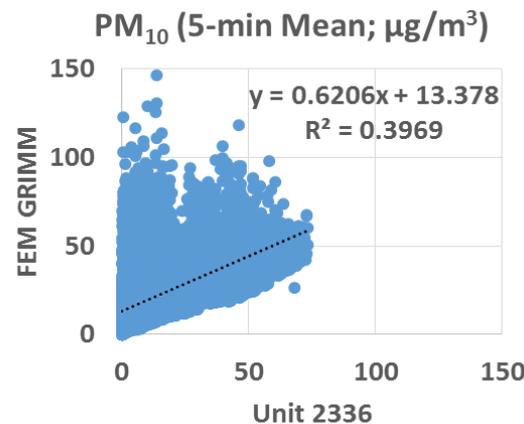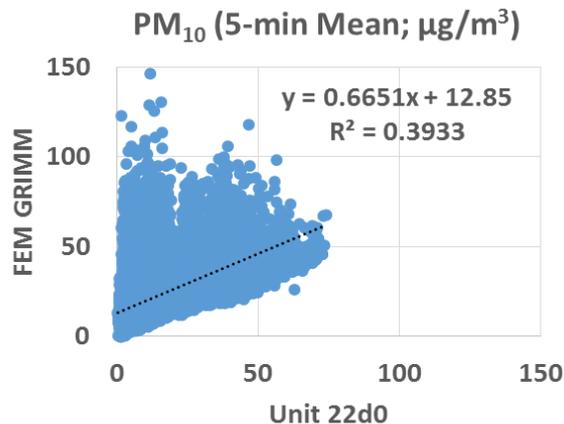
Purple Air Sensor vs FEM GRIMM (PM$_{1.0}$ Mass; 1-hr mean)
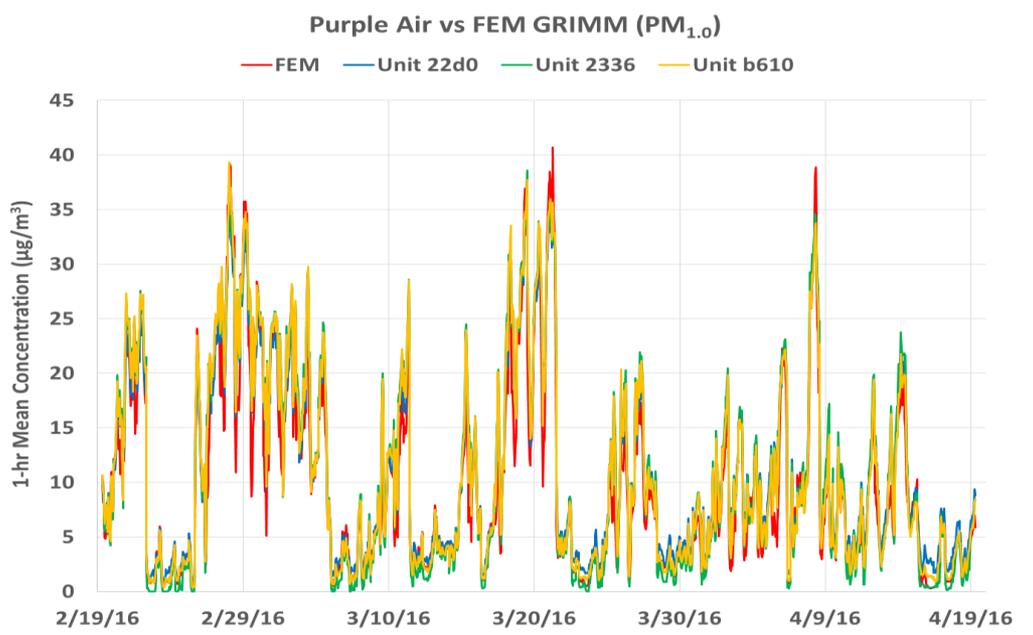
Purple Air vs FEM GRIMM (PM$_{1.0}$)

— FEM   — Unit 22d0   — Unit 2336   — Unit b610

- Purple Air PM$_{1.0}$ mass measurements correlate well with the corresponding FEM GRIMM data (R^2 > 0.94)

PM$_{1.0}$ (1-hr Mean; μg/m^3)

$y = 0.9825x - 1.0189$
$R^2 = 0.9467$

Unit 22d0

PM$_{1.0}$ (1-hr Mean; μg/m^3)

$y = 0.8757x + 0.3316$
$R^2 = 0.9405$

Unit 2336

PM$_{1.0}$ (1-hr Mean; μg/m^3)

$y = 0.912x - 0.1427$
$R^2 = 0.952$

Unit b610
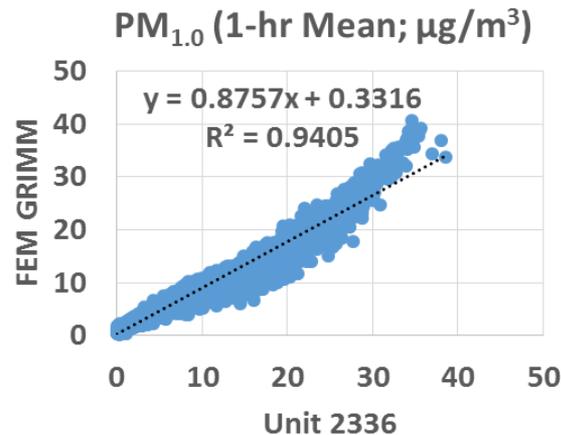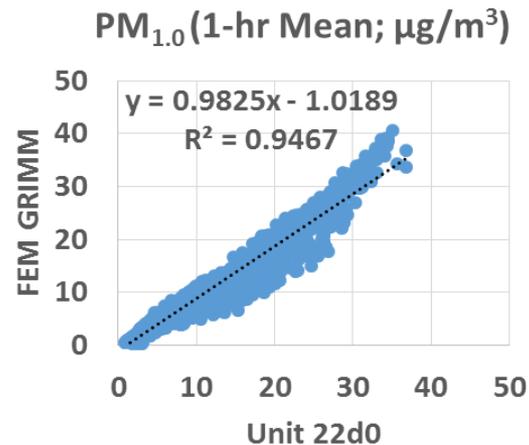
Purple Air Sensor vs FEM GRIMM (PM$_{2.5}$; 1-hr mean)
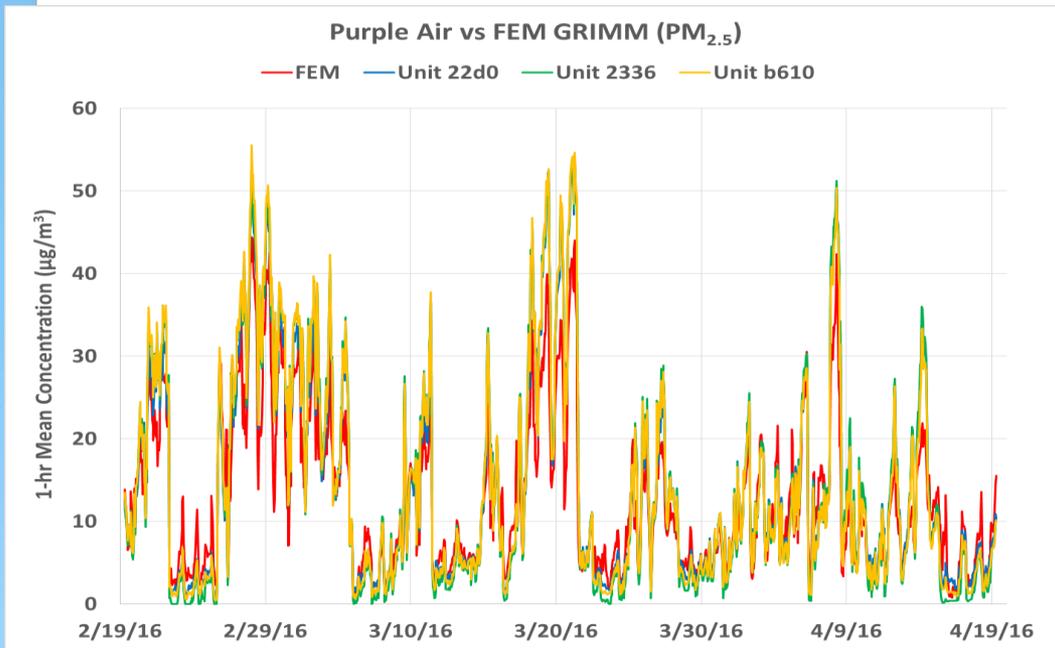
Purple Air vs FEM GRIMM (PM$_{2.5}$)

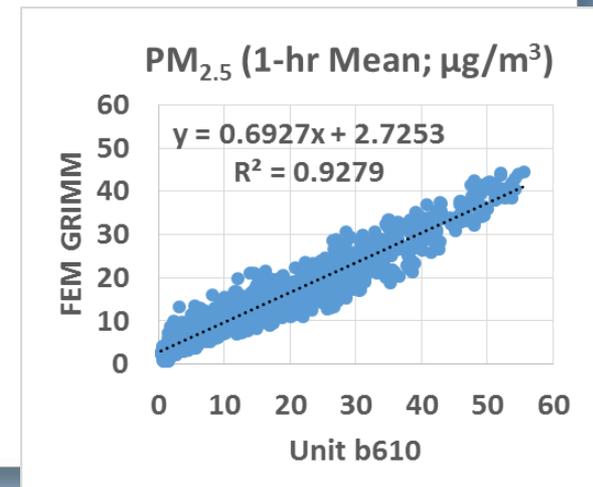— FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{2.5}$ mass measurements correlate well with the corresponding FEM GRIMM data (R^2 > 0.91)

PM$_{2.5}$ (1-hr Mean; µg/m^3)

$y = 0.7271x + 2.2696$
$R^2 = 0.9128$

Unit 22d0

PM$_{2.5}$ (1-hr Mean; µg/m^3)

$y = 0.6783x + 3.0625$
$R^2 = 0.9168$

Unit 2336

PM$_{2.5}$ (1-hr Mean; µg/m^3)

$y = 0.6927x + 2.7253$
$R^2 = 0.9279$

Unit b610
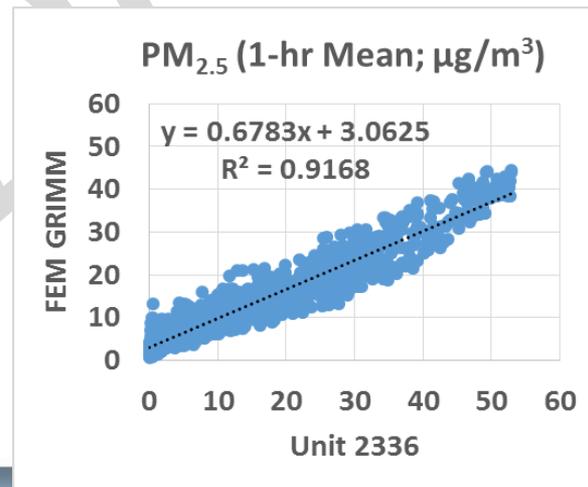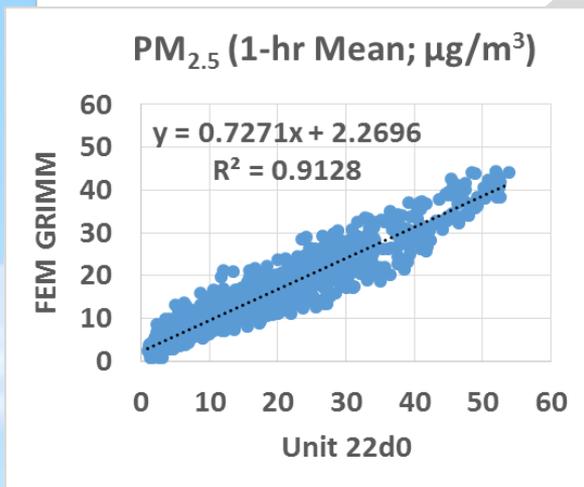
Purple Air Sensor vs FEM GRIMM (PM_{10}; 1-hr mean)
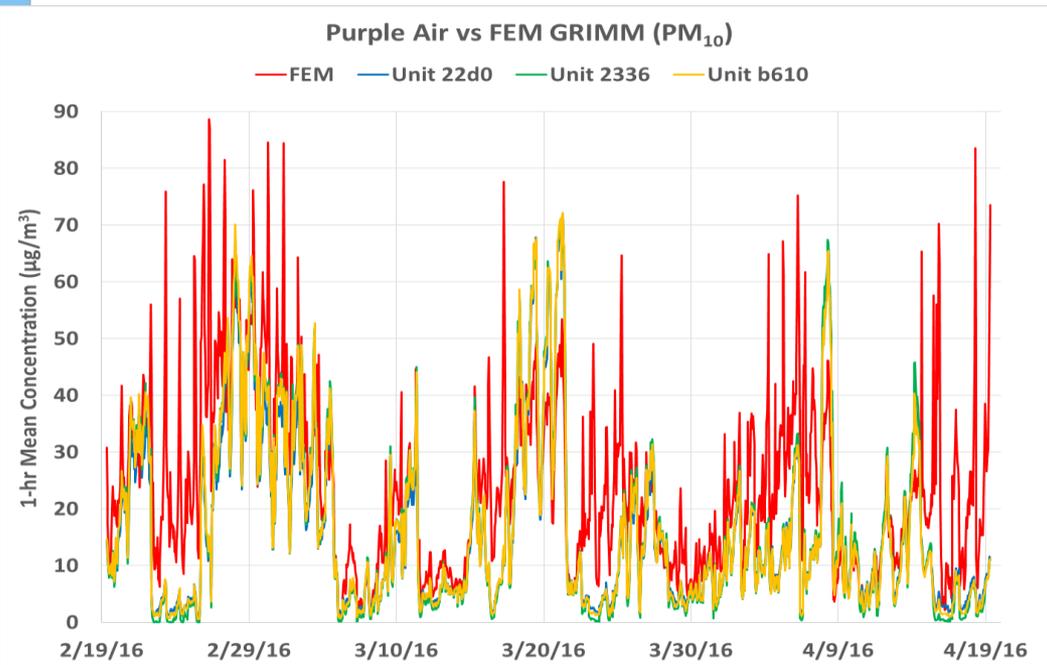
Purple Air vs FEM GRIMM (PM_{10})

- FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM_{10} mass measurements show a modest correlation with the corresponding FEM GRIMM data ($R^2 < 0.45$)

PM_{10} (1-hr Mean; $\mu g/m^3$)

$y = 0.6646x + 12.876$
$R^2 = 0.4282$

Unit 22d0

PM_{10} (1-hr Mean; $\mu g/m^3$)

$y = 0.6195x + 13.416$
$R^2 = 0.432$

Unit 2336

PM_{10} (1-hr Mean; $\mu g/m^3$)

$y = 0.6448x + 12.981$
$R^2 = 0.4483$

Unit b610

10
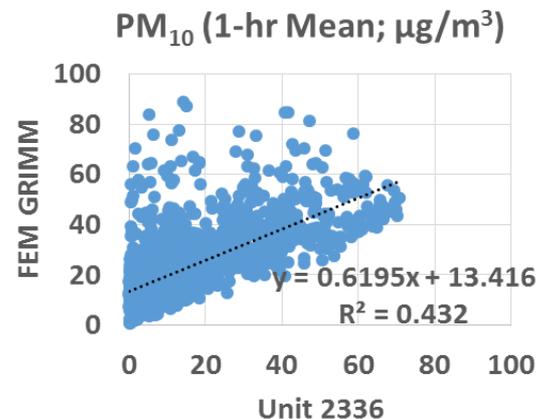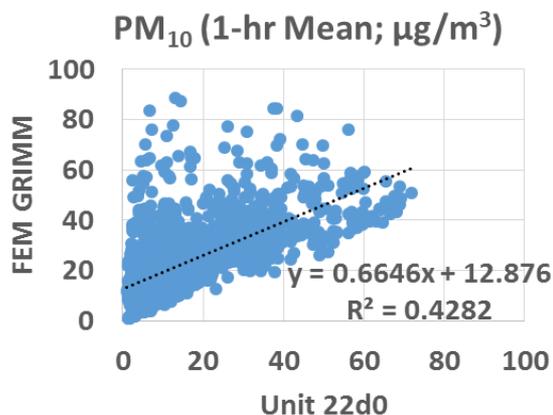
Purple Air Sensor vs FEM GRIMM (PM$_{1.0}$ Mass; 24-hr mean)
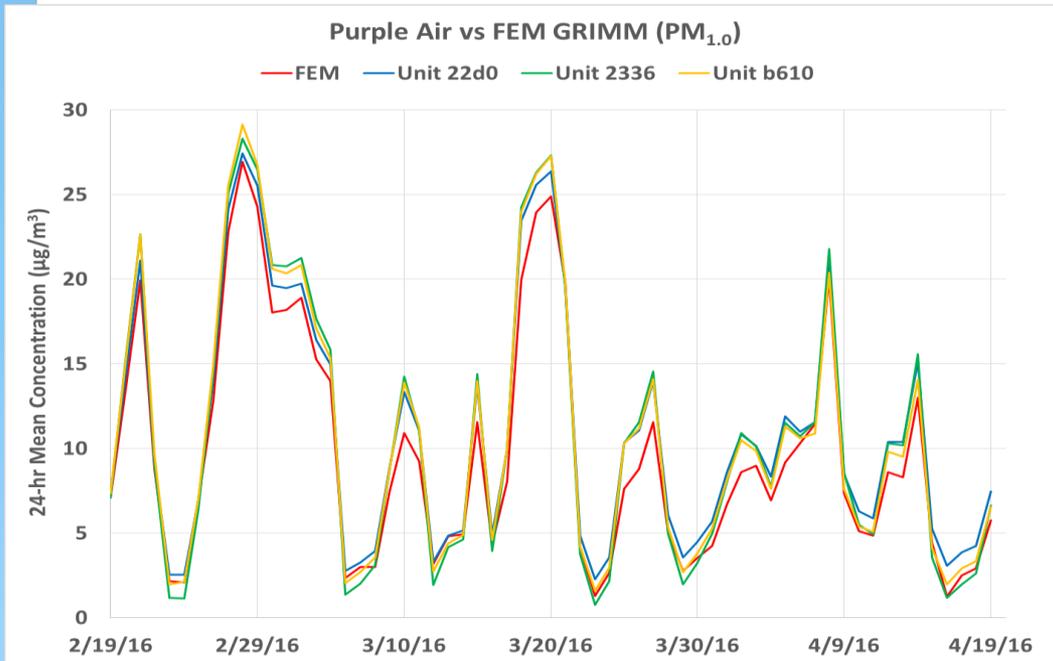
Purple Air vs FEM GRIMM (PM$_{1.0}$)
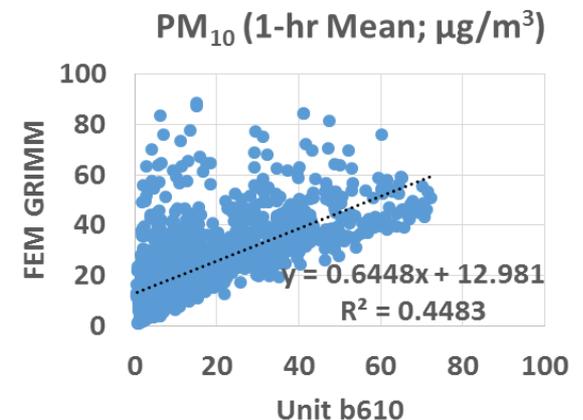
— FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{1.0}$ mass measurements correlate well with the corresponding FEM GRIMM data ($R^2 > 0.98$)

PM$_{1.0}$ (24-hr Mean; μg/m^3)

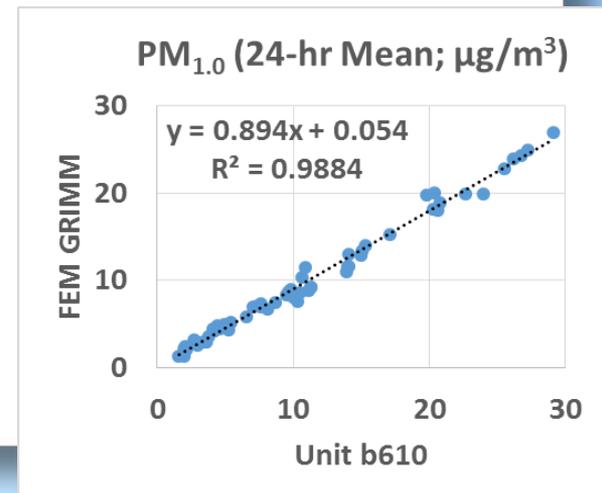$y = 0.9695x - 0.8786$
$R^2 = 0.9884$

Unit 22d0

PM$_{1.0}$ (24-hr Mean; μg/m^3)

$y = 0.8623x + 0.4733$
$R^2 = 0.9834$

Unit 2336

PM$_{1.0}$ (24-hr Mean; μg/m^3)

$y = 0.894x + 0.054$
$R^2 = 0.9884$

Unit b610
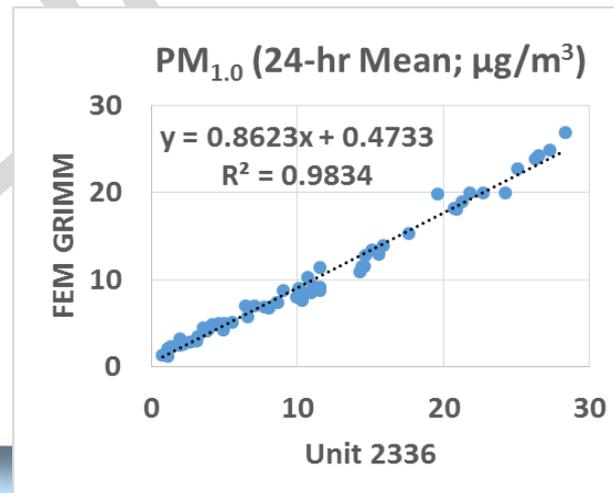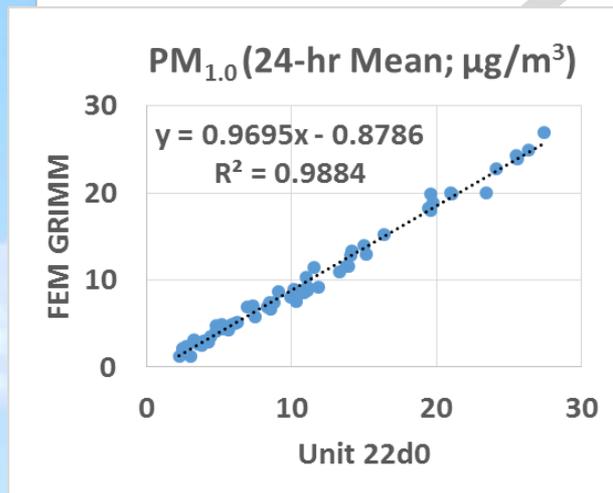
Purple Air Sensor vs FEM GRIMM (PM$_{2.5}$; 24-hr mean)
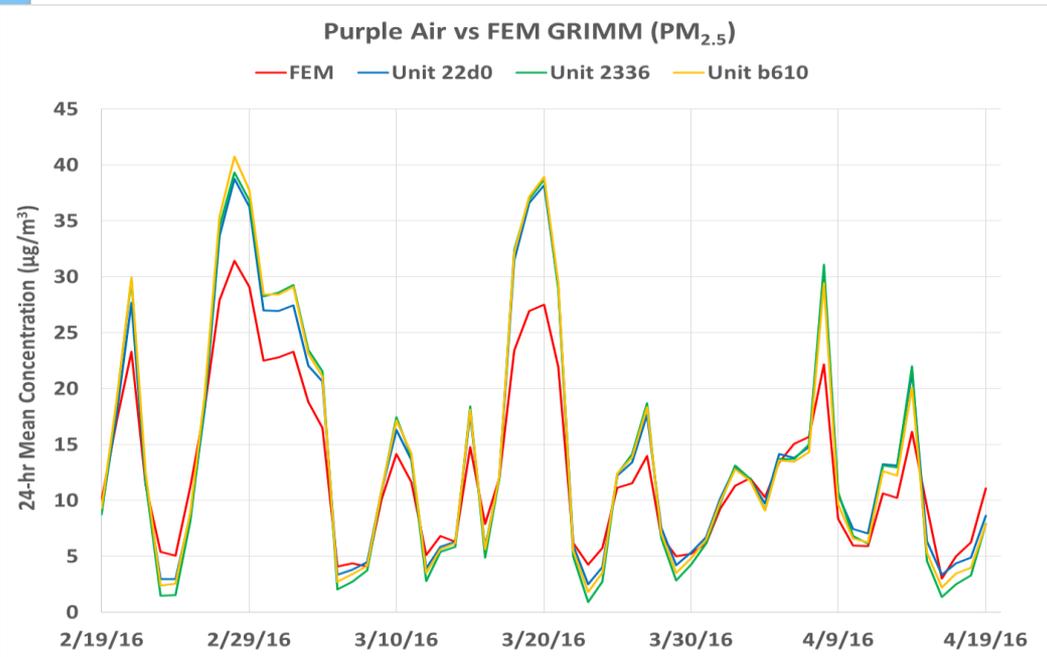
Purple Air vs FEM GRIMM (PM$_{2.5}$)

— FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{2.5}$ mass measurements correlate well with the corresponding FEM GRIMM data ($R^2 > 0.96$)

PM$_{2.5}$ (24-hr Mean; μg/m^3)

$y = 0.7134x + 2.4996$
$R^2 = 0.9676$

Unit 22d0

PM$_{2.5}$ (24-hr Mean; μg/m^3)

$y = 0.6635x + 3.3068$
$R^2 = 0.9682$

Unit 2336

PM$_{2.5}$ (24-hr Mean; μg/m^3)

$y = 0.6747x + 3.0201$
$R^2 = 0.9739$

Unit b610
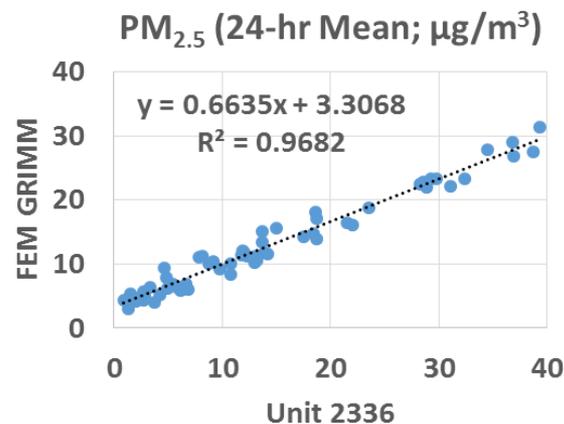
Purple Air Sensor vs FEM GRIMM (PM$_{10}$; 24-hr mean)

Purple Air vs FEM GRIMM (PM$_{10}$)

- FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{10}$ mass measurements show a modest correlation with the corresponding FEM GRIMM data ($R^2 < 0.50$).

PM$_{10}$ (24-hr Mean; μg/m^3)
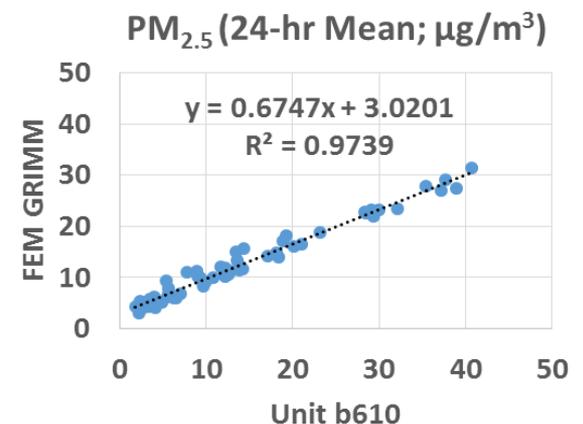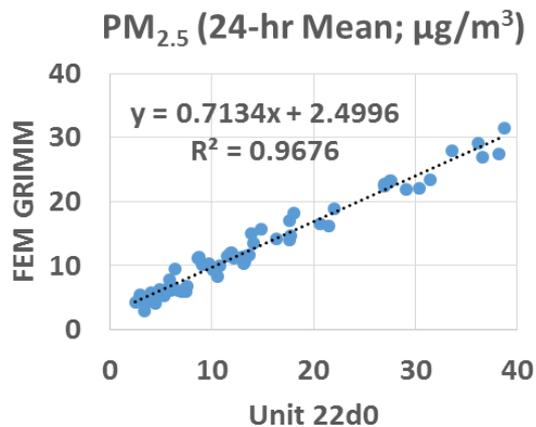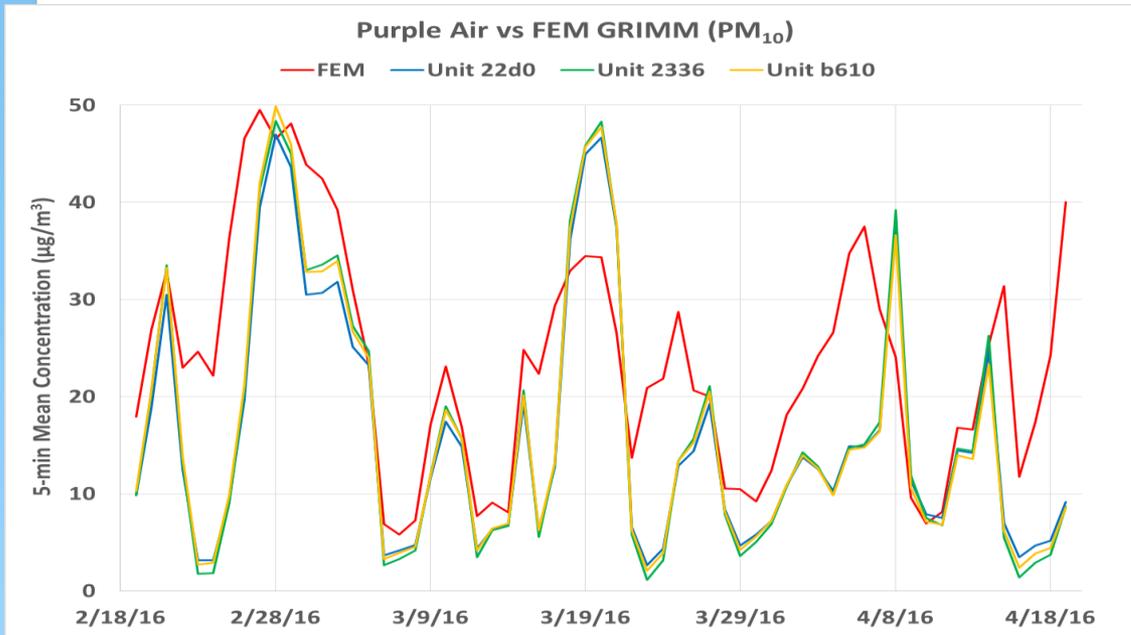
$y = 0.6485x + 13.357$
$R^2 = 0.4779$

Unit 22d0

PM$_{10}$ (24-hr Mean; μg/m^3)

$y = 0.6017x + 13.932$
$R^2 = 0.4799$

Unit 2336

PM$_{10}$ (24-hr Mean; μg/m^3)

$y = 0.6244x + 13.542$
$R^2 = 0.4962$

Unit b610
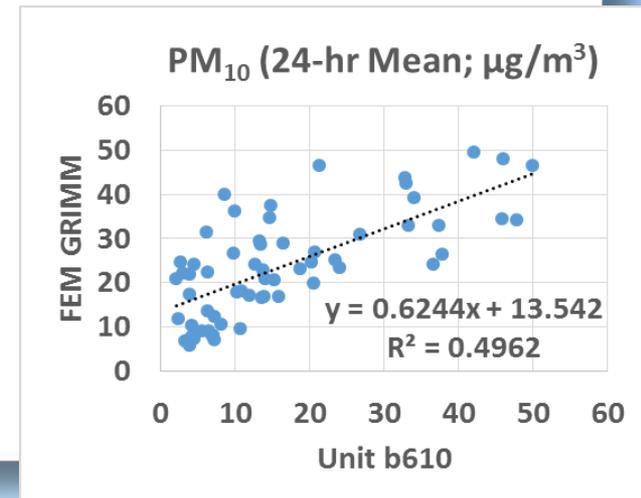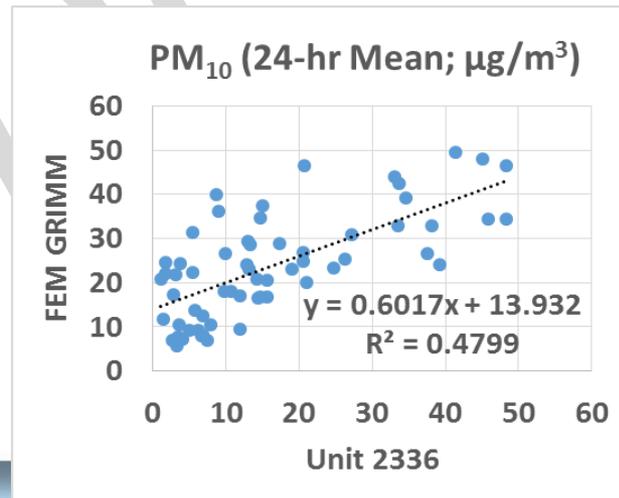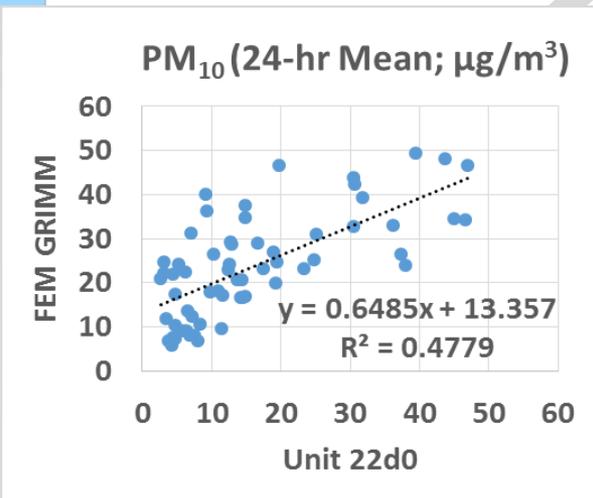
Purple Air Sensor vs FEM BAM (PM$_{2.5}$; 1-hr mean)

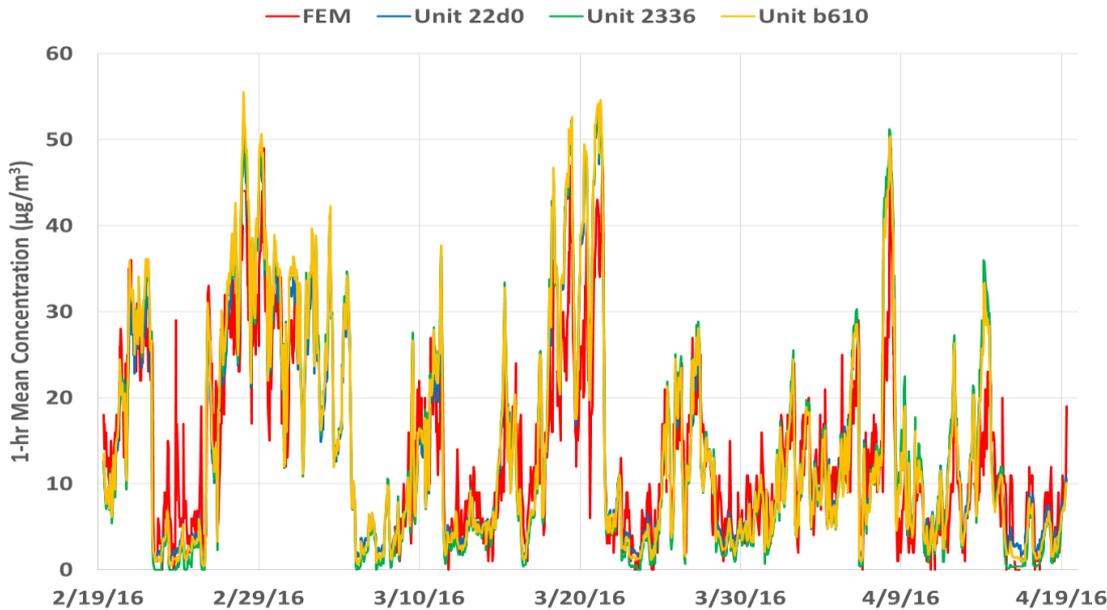**Purple Air vs FEM BAM (PM$_{2.5}$)**

Legend: FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{2.5}$ mass measurements correlate well with the corresponding FEM BAM data (R^2 > 0.77)
- The three sensor units tracked the diurnal PM variations recorded by the FEM BAM instrument well
- Measurements from all three Purple Air devices are quite accurate when compared to the corresponding FEM BAM data

PM$_{2.5}$ (µg/m^3)

$y = 0.7099x + 3.2227$
$R^2 = 0.7754$

Unit 22d0

PM$_{2.5}$ (µg/m^3)

$y = 0.6637x + 3.995$
$R^2 = 0.7773$

Unit 2336

PM$_{2.5}$ (µg/m^3)
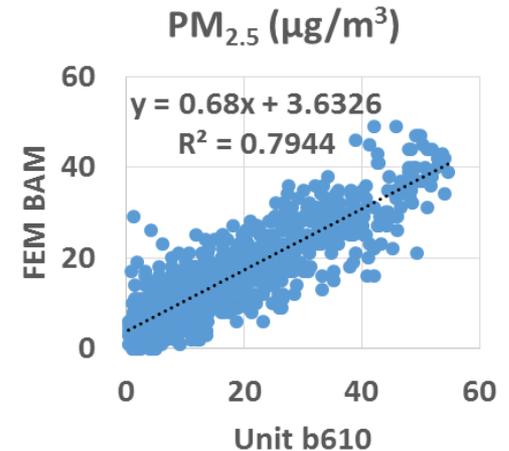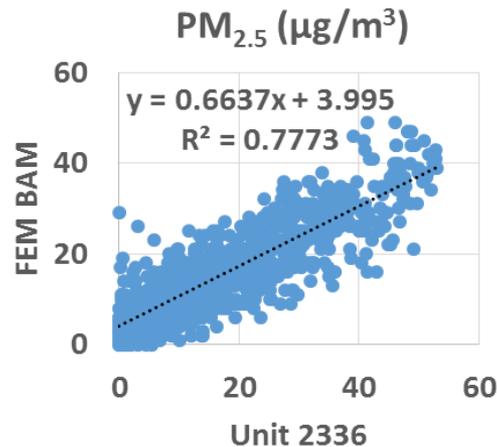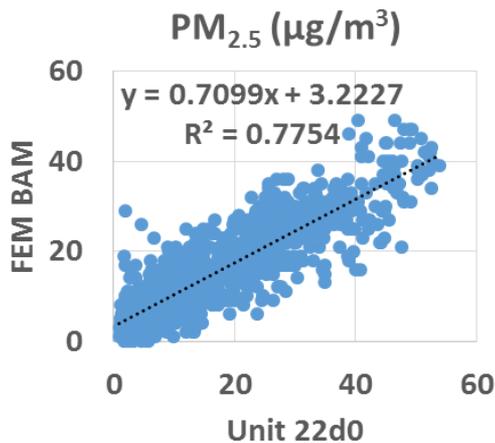
$y = 0.68x + 3.6326$
$R^2 = 0.7944$

Unit b610

Purple Air Sensor vs FEM BAM (PM$_{2.5}$; 24-hr mean)

Purple Air vs FEM BAM (PM$_{2.5}$)

— FEM — Unit 22d0 — Unit 2336 — Unit b610

- Purple Air PM$_{2.5}$ mass measurements correlate well with the corresponding FEM BAM data ($R^2 > 0.90$)
- The three sensor units tracked the diurnal PM variations recorded by the FEM BAM instrument well
- Measurements from all three Purple Air devices are quite accurate when compared to the corresponding FEM BAM data

PM$_{2.5}$ (µg/m^3)

$y = 0.7409x + 2.8604$
$R^2 = 0.9067$

FEM BAM — Unit 22d0

PM$_{2.5}$ (µg/m^3)

$y = 0.6961x + 3.6259$
$R^2 = 0.9168$

FEM BAM — Unit 2336

PM$_{2.5}$ (µg/m^3)

$y = 0.7081x + 3.3161$
$R^2 = 0.9281$

FEM BAM — Unit b610

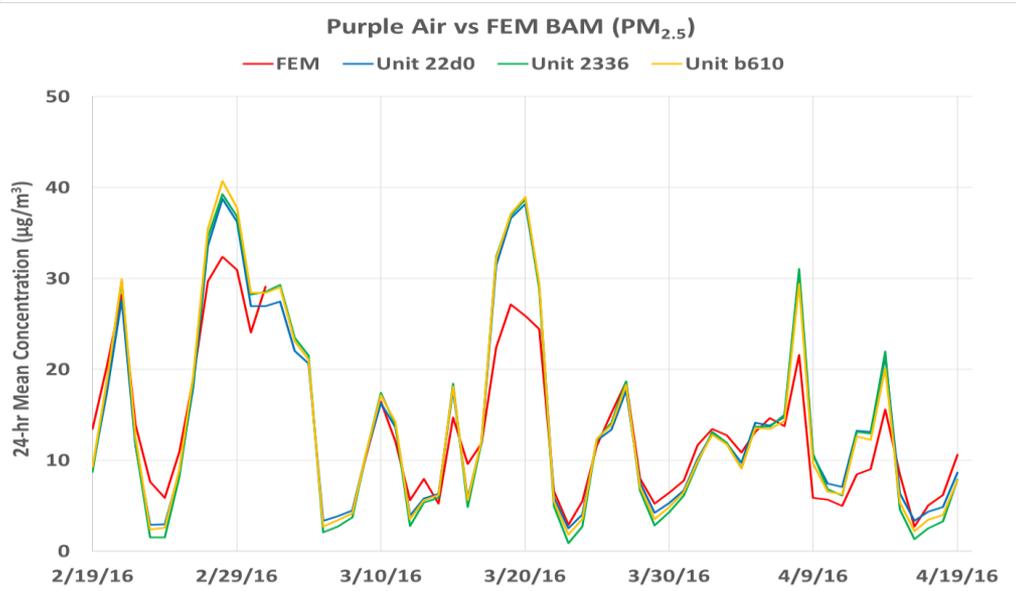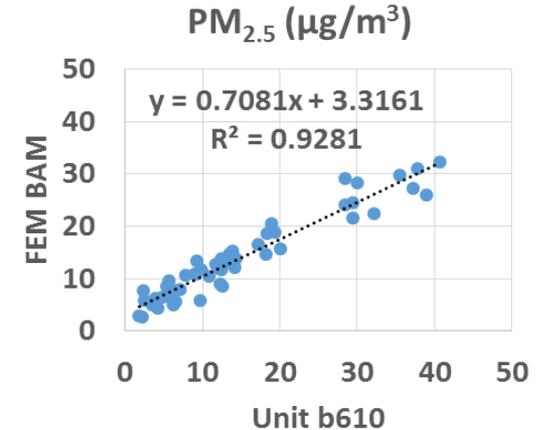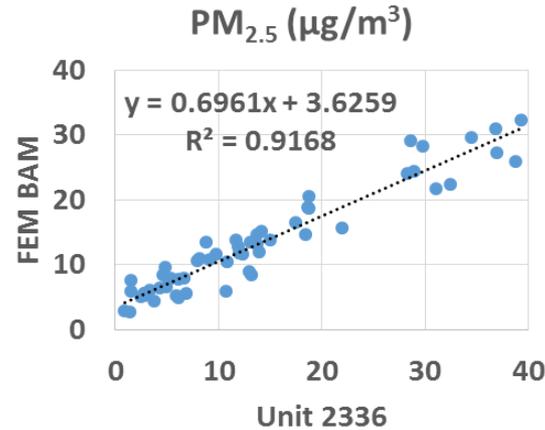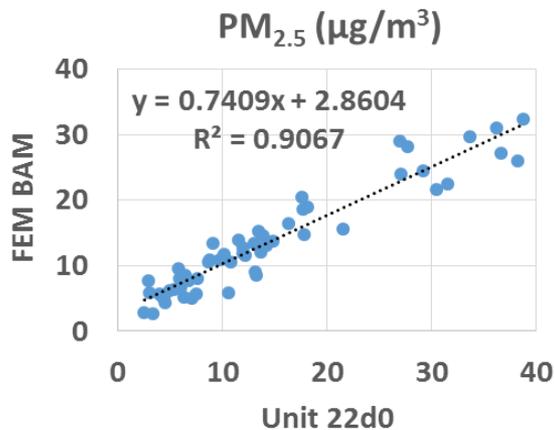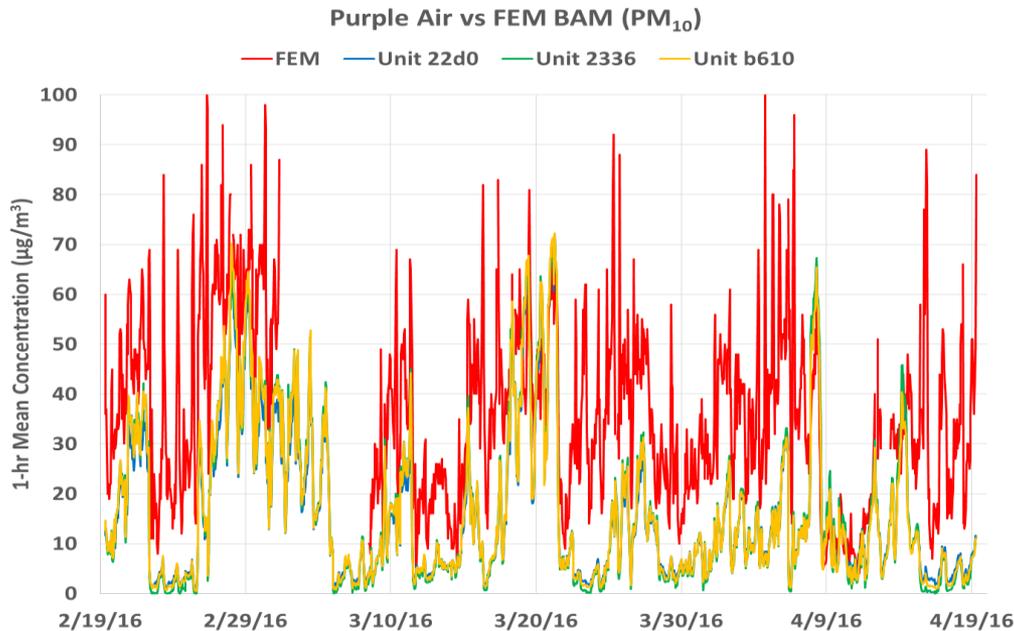15

Purple Air Sensor vs FEM BAM (PM$_{10}$; 1-hr mean)

Purple Air vs FEM BAM (PM$_{10}$)

- Purple Air PM$_{10}$ mass measurements show a low correlation with the corresponding FEM BAM data ($R^2 < 0.35$)
- The three sensor units do not always track the diurnal variations recorded by the FEM BAM instrument
- Purple Air PM$_{10}$ measurements are underestimated with respect to the corresponding FEM BAM data

PM$_{10}$ ($\mu g/m^3$)
$y = 0.6845x + 25.189$
$R^2 = 0.3219$

PM$_{10}$ ($\mu g/m^3$)
$y = 0.6407x + 25.704$
$R^2 = 0.3264$

PM$_{10}$ ($\mu g/m^3$)
$y = 0.6708x + 25.208$
$R^2 = 0.3424$
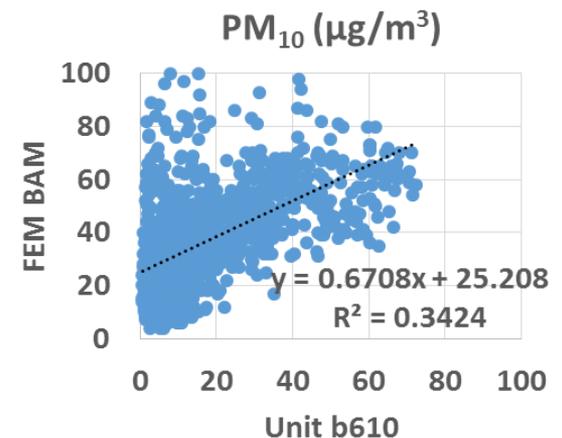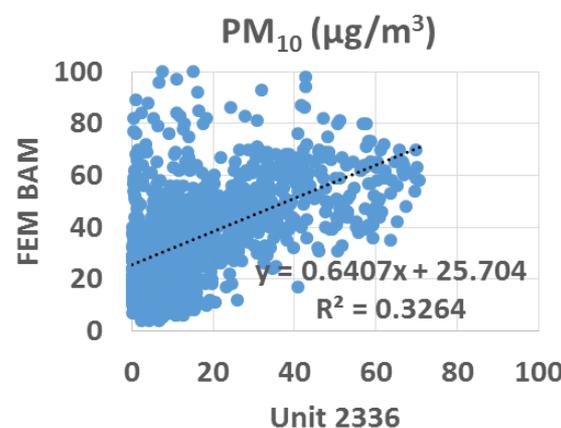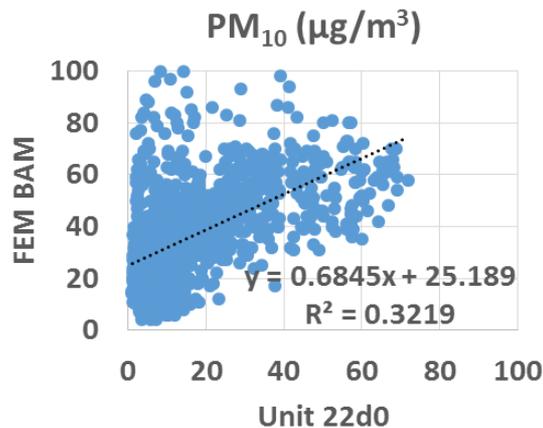
Purple Air Sensor vs FEM BAM (PM_{10}; 24-hr mean)
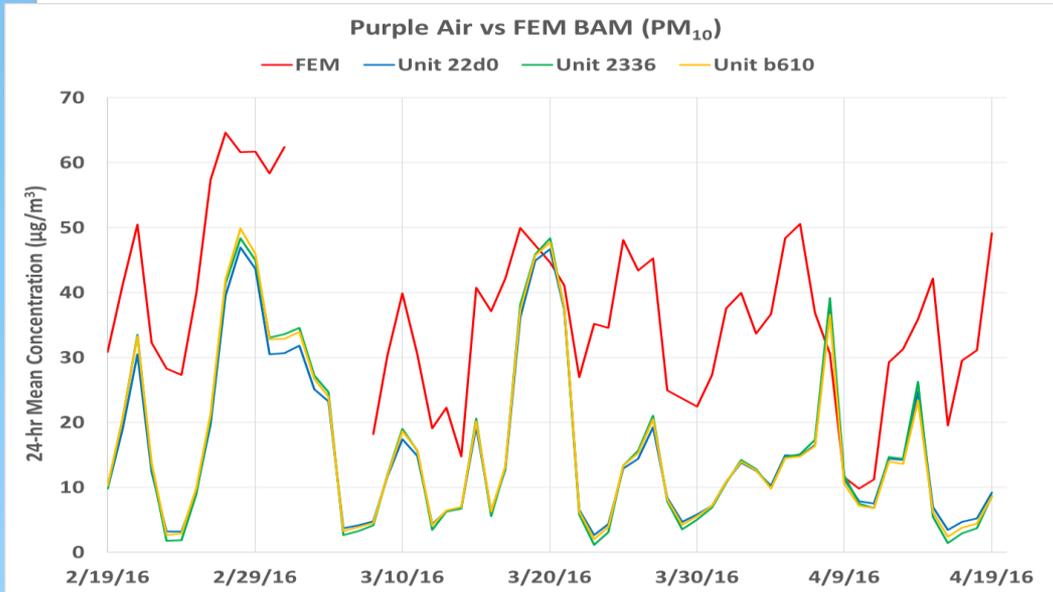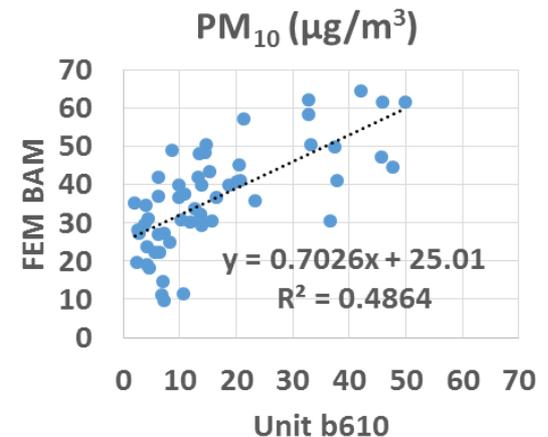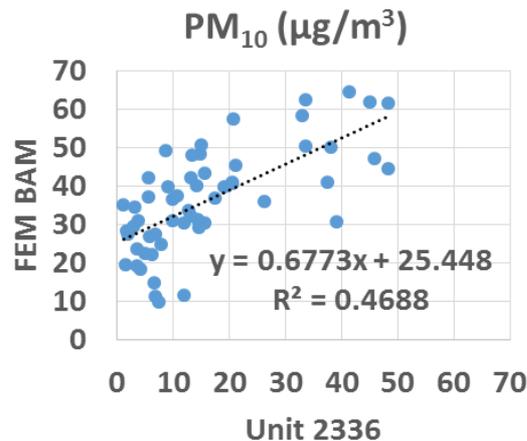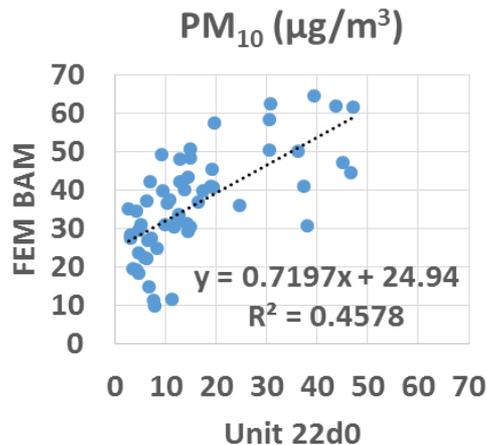
Purple Air vs FEM BAM (PM_{10})

- Purple Air PM_{10} mass measurements show a modest correlation with the corresponding FEM BAM data ($R^2 < 0.49$)
- The three sensor units do not always track the diurnal variations recorded by the FEM BAM instrument
- Purple Air PM_{10} measurements are underestimated with respect to the corresponding FEM BAM data

PM_{10} ($\mu g/m^3$) — Unit 22d0

$y = 0.7197x + 24.94$
$R^2 = 0.4578$

PM_{10} ($\mu g/m^3$) — Unit 2336

$y = 0.6773x + 25.448$
$R^2 = 0.4688$

PM_{10} ($\mu g/m^3$) — Unit b610

$y = 0.7026x + 25.01$
$R^2 = 0.4864$

Discussion

- Overall, the three **Purple Air PM Sensors** were very reliable (data recovery was close to 100% for all units tested) and characterized by very low intra-model variability
- Purple Air sensor $PM_{1.0}$ and $PM_{2.5}$ data was highly correlated ($R^2 > 0.90$) to the corresponding measurements collected using a substantially more expensive FEM instrument (GRIMM). However, the sensor vs GRIMM correlation for PM_{10} was only modest ($R^2 < 0.45$)
- Similarly, the Purple Air sensor $PM_{2.5}$ data was very well correlated ($R^2 > 0.78$) to the corresponding measurements collected using an FEM BAM. Also in this case the sensor vs BAM correlation for PM_{10} was only modest ($R^2 < 0.34$)
- Although no sensor calibration was performed by SCAQMD Staff prior to the beginning of this test, the $PM_{1.0}$ and $PM_{2.5}$ data collected by all three sensor units were quite accurate
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors over different / more extreme environmental conditions

- <u>All results are still preliminary</u>